

Isotope Production Calculations Using FISPIN

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ABOUT NNL

Isotope Production Calculations Using FISPIN

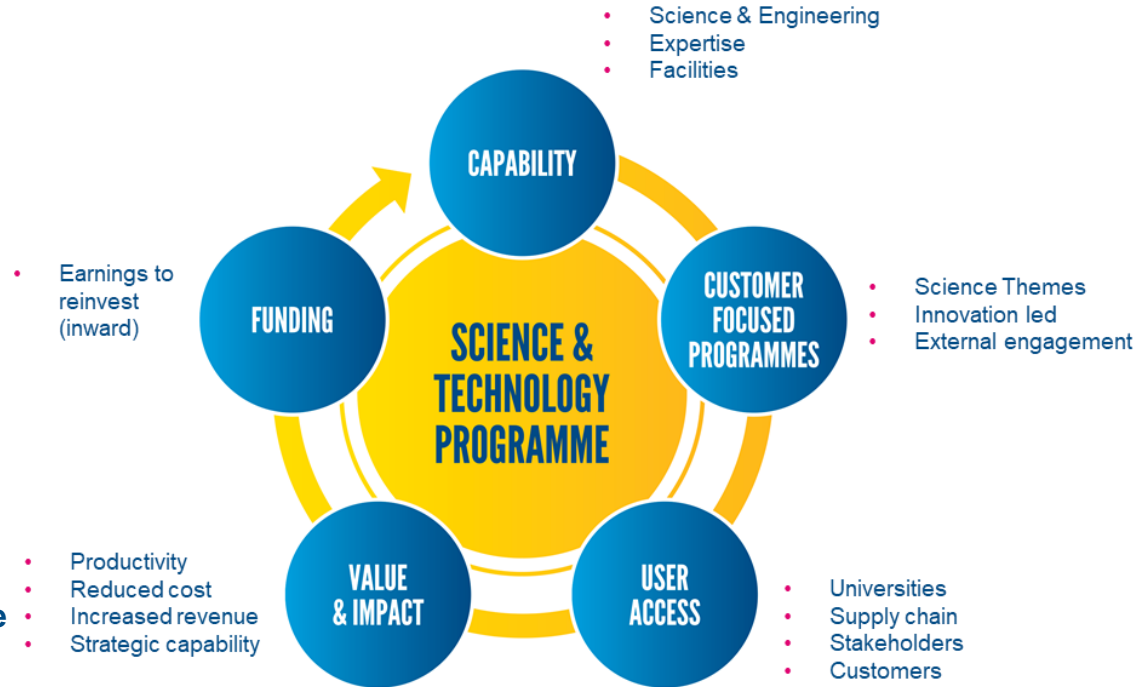
- NNL is the UK's National Nuclear Laboratory which operates on an autonomous commercial basis
- NNL is owned by the UK government and has three roles prescribed to it, shown in the figure opposite
- NNL operates world leading facilities doing world class science
- Over 10,000 person years of nuclear industry experience across the whole fuel lifecycle
- 6 locations across the UK including high active laboratories
- Principal customers include: Sellafield Ltd, EDF Energy, Ministry of Defence, BEIS, Westinghouse, US Department of Energy, Nuclear Decommissioning Authority (NDA)



NNL'S CORE SCIENCE THEMES

Isotope Production Calculations Using FISPIN

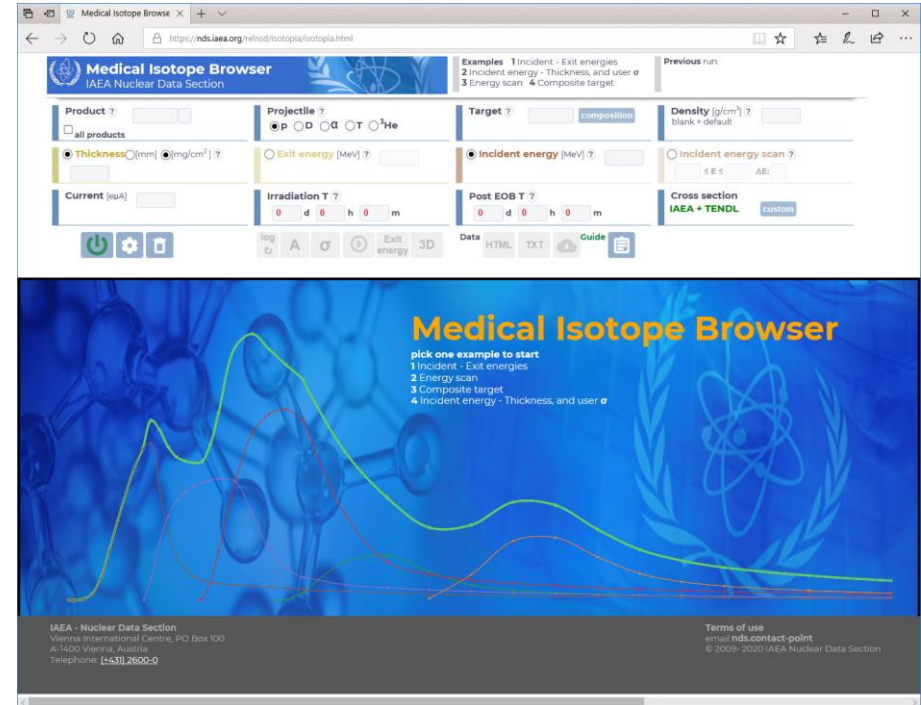
- ~£1.8m investment per year in Core Science Themes
- 9 Core Science Themes, enabling NNL to:
 - **Develop expertise**
 - **Work with the supply chain**
 - **Build strategic capability on behalf of the UK**
- Advanced Recycle and Isotope Separation (ARIS)
 - **Identified growth areas include the use of accelerator-based systems for isotope production**



ACCELERATOR ISOTOPE PRODUCTION

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- Accelerator based isotope production has tended to focus on charged particle sources
- Some tools have been created (ISOTOPIA) that can make conversion assessments for these reactions
- More recent interest in neutron induced isotope production from accelerator based systems
 - **Replace research reactors**
 - **Cheaper (commissioning and decommissioning)**
 - **Fewer safety implications**
 - **Less waste and less hazardous wastes**



- Nuclear data provides a wealth of information to tap into but can be difficult to utilise
- With so much data available, it can take a lot of work to sift through and understand possible production routes from an idea
- Everything is possible, but how likely are the interactions we want? And what might be the downfalls of a production route? What else do we end up with?

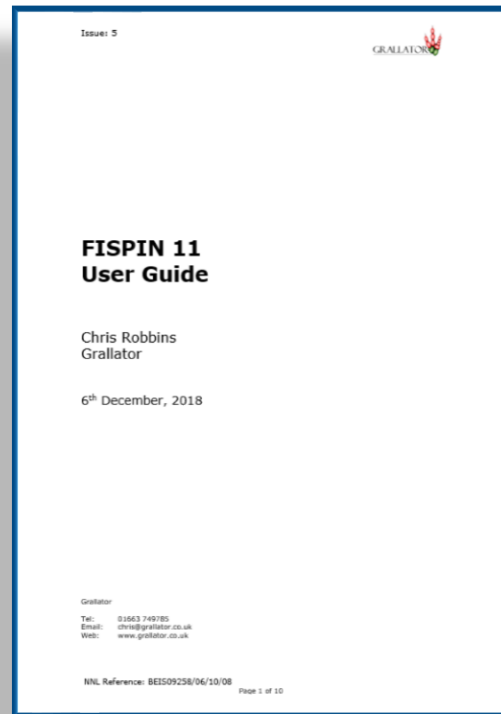
Basic properties

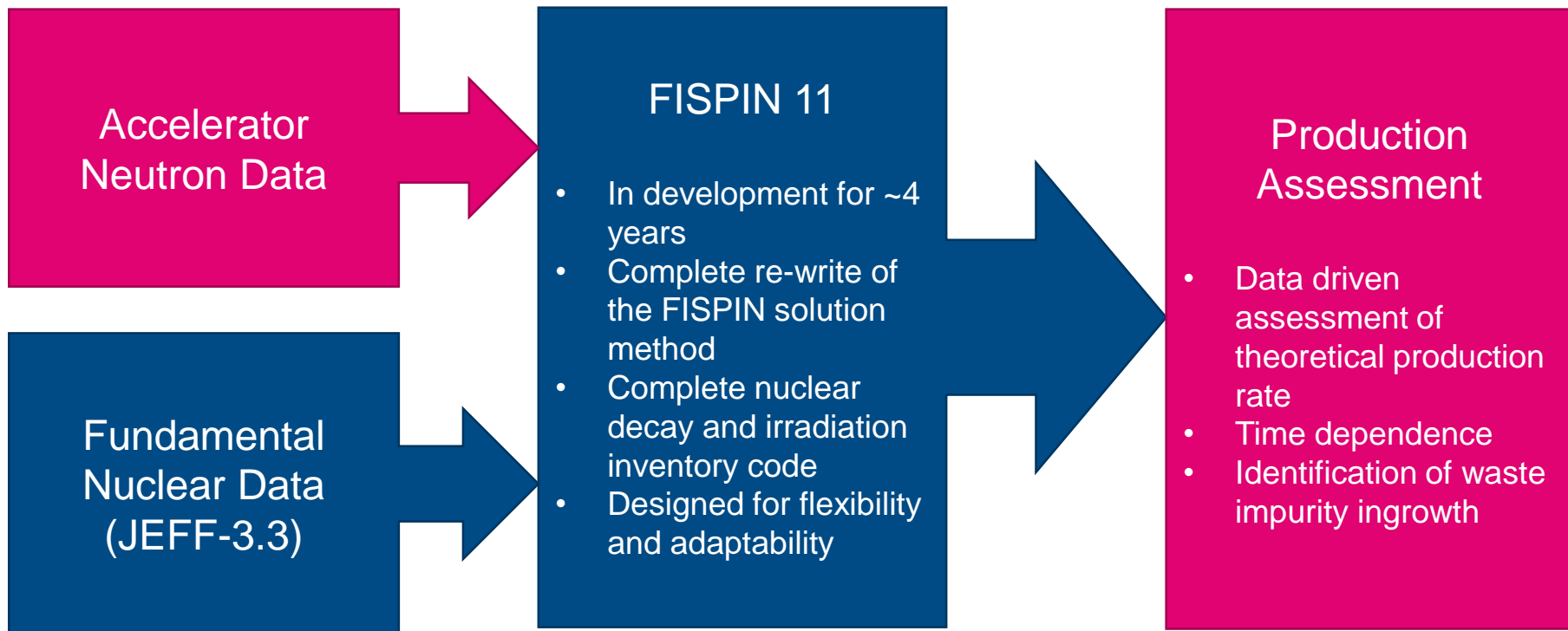
1.00794 atomic weight 1H 1.00794	4.00260 atomic weight He 4.00260	6.941 atomic weight Li 6.941	9.0122 atomic weight Be 9.0122	10.81 atomic weight B 10.81	12.011 atomic weight C 12.011	14.007 atomic weight N 14.007	15.999 atomic weight O 15.999	18.998 atomic weight F 18.998	20.180 atomic weight Ne 20.180	22.990 atomic weight Na 22.990	24.305 atomic weight Mg 24.305	26.982 atomic weight Al 26.982	28.086 atomic weight Si 28.086	30.974 atomic weight P 30.974	32.06 atomic weight S 32.06	35.45 atomic weight Cl 35.45	39.948 atomic weight Ar 39.948	39.098 atomic weight K 39.098	40.078 atomic weight Ca 40.078	44.956 atomic weight Sc 44.956	47.88 atomic weight Ti 47.88	50.942 atomic weight V 50.942	51.996 atomic weight Cr 51.996	54.938 atomic weight Mn 54.938	55.845 atomic weight Fe 55.845	58.933 atomic weight Co 58.933	58.693 atomic weight Ni 58.693	58.933 atomic weight Cu 58.933	58.933 atomic weight Zn 58.933	58.933 atomic weight Ga 58.933	58.933 atomic weight Ge 58.933	58.933 atomic weight As 58.933	58.933 atomic weight Se 58.933	58.933 atomic weight Br 58.933	58.933 atomic weight Kr 58.933	58.933 atomic weight Rb 58.933	58.933 atomic weight Sr 58.933	58.933 atomic weight Y 58.933	58.933 atomic weight Zr 58.933	58.933 atomic weight Nb 58.933	58.933 atomic weight Mo 58.933	58.933 atomic weight Tc 58.933	58.933 atomic weight Ru 58.933	58.933 atomic weight Rh 58.933	58.933 atomic weight Pd 58.933	58.933 atomic weight Ag 58.933	58.933 atomic weight Cd 58.933	58.933 atomic weight In 58.933	58.933 atomic weight Sn 58.933	58.933 atomic weight Sb 58.933	58.933 atomic weight Te 58.933	58.933 atomic weight I 58.933	58.933 atomic weight Xe 58.933	58.933 atomic weight Ba 58.933	58.933 atomic weight La 58.933	58.933 atomic weight Ce 58.933	58.933 atomic weight Pr 58.933	58.933 atomic weight Nd 58.933	58.933 atomic weight Pm 58.933	58.933 atomic weight Sm 58.933	58.933 atomic weight Eu 58.933	58.933 atomic weight Gd 58.933	58.933 atomic weight Tb 58.933	58.933 atomic weight Dy 58.933	58.933 atomic weight Ho 58.933	58.933 atomic weight Er 58.933	58.933 atomic weight Tm 58.933	58.933 atomic weight Yb 58.933	58.933 atomic weight Lu 58.933	58.933 atomic weight Hf 58.933	58.933 atomic weight Ta 58.933	58.933 atomic weight W 58.933	58.933 atomic weight Re 58.933	58.933 atomic weight Os 58.933	58.933 atomic weight Ir 58.933	58.933 atomic weight Pt 58.933	58.933 atomic weight Au 58.933	58.933 atomic weight Hg 58.933	58.933 atomic weight Tl 58.933	58.933 atomic weight Pb 58.933	58.933 atomic weight Bi 58.933	58.933 atomic weight Po 58.933	58.933 atomic weight At 58.933	58.933 atomic weight Rn 58.933	58.933 atomic weight Fr 58.933	58.933 atomic weight Ra 58.933	58.933 atomic weight Ac 58.933	58.933 atomic weight Th 58.933	58.933 atomic weight Pa 58.933	58.933 atomic weight U 58.933	58.933 atomic weight Np 58.933	58.933 atomic weight Pu 58.933	58.933 atomic weight Am 58.933	58.933 atomic weight Cm 58.933	58.933 atomic weight Bk 58.933	58.933 atomic weight Cf 58.933	58.933 atomic weight Es 58.933	58.933 atomic weight Fm 58.933	58.933 atomic weight Md 58.933	58.933 atomic weight No 58.933	58.933 atomic weight Lr 58.933
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- Given the manual nature of such assessments, they're currently dependent on the knowledge of subject matter experts, and to complete in detail require significant time – we're limited to “back of envelope calculations” for most discussions
- There are plenty of ideas of what could be done with an accelerator for isotope production – building an expertise in assessing their viability would allow us to prioritise based on theoretical feasibility
- **Enter the “Production Rate Assessment Tool”!**



- FISPIN is a standard code used in the UK over the last 60 years to calculate the composition and evolution of irradiated nuclear fuel and related waste streams
- FISPIN11, has been in development for approximately 4 years and was a complete re-write of the FISPIN solution method
- The code can now track more decay chains than we've ever been able to track previously
- FISPIN11 has a number of improvements over its predecessor, including:
 - **Improved efficiency**
 - **Improved ease of use and maintenance**
 - **Inclusion of the updated FISGUI (FISPIN Graphical User Interface)**
 - **Increased flexibility (wrapper capability)**





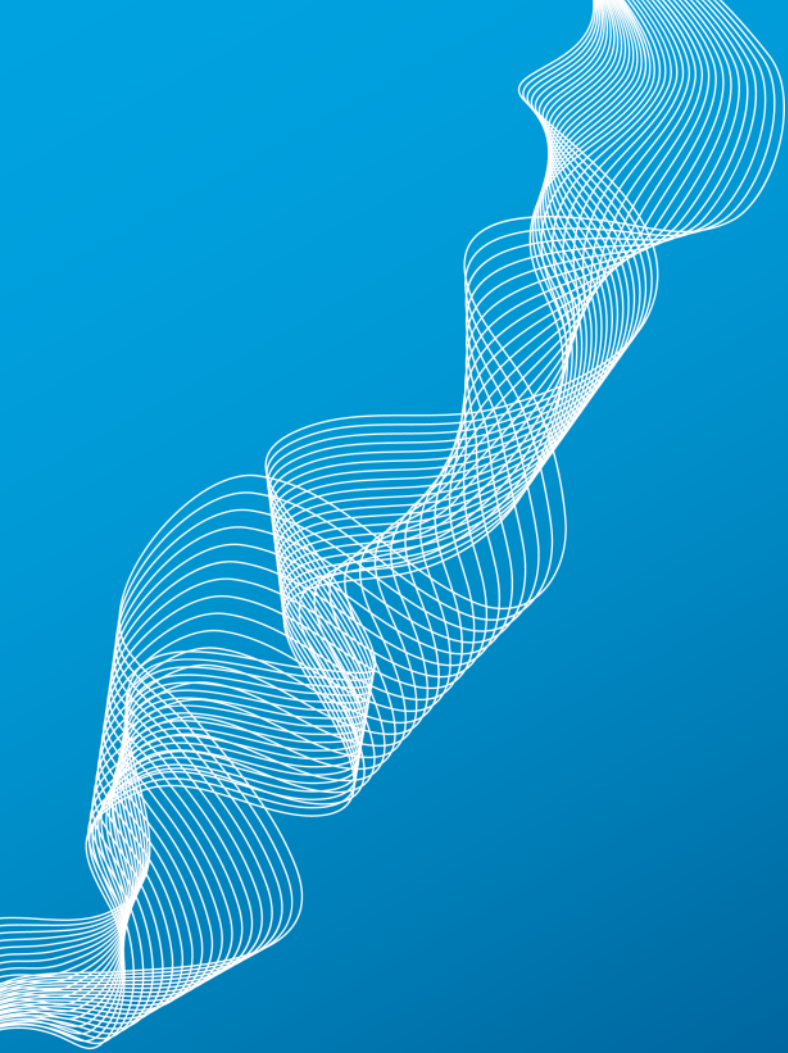
- Models are no longer limited by computational capabilities, but by the uncertainties in nuclear data
 - **Nuclear decay data**
 - **Neutron transmutation cross-sections**
- Any uncertainty from FISPIN11 will come from the fundamental nuclear data
- Some data is less tested for accelerator applications
- The tool will be very reliant on the quality of the underpinning nuclear data



DEVELOPMENT AIMS

- In development (2020-2021)
- Develop initial Production Rate Assessment Tool FISPIN wrapper
 - **Key assumptions – thin targets, neutron only sources**
 - **Methodology for handling accelerator based neutron energy spectrum**
- Collate baseline accelerator information – neutron energy ranges, fluence
- Assess performance on initial concepts – lanthanides from EURO-GANEX
 - **Process developed for co-separating transuranium elements from irradiated nuclear fuels**
 - **Aims to identify which lanthanide feeds would be a suitable source of useful isotopes**

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo
		*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
		**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr



Thank you for listening!
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